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EFFECT OF SOME VARIABLES ON THORON PROGENY IN ARTIFICIAL RADIOACTIVE ENVIRONMENTS

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by

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ABSTRACT

The effect of aerosol concentration, relative humidity, mixing fans, negative ion-generators, and a small electrostatic dust precipitator on airborne thoron progeny activity concentration has been investigated. Measurements were carried out in a Radon/Thoron Test Facility (RTTF) of the walk-in type. Thoron progeny concentration levels increased substantially with increasing aerosol concentration. The operation of mixing fans and ion-generators had a substantial and opposite effect to aerosol concentration on thoron progeny levels.

Key words: Thoron progeny; Radioactivity; Environment.

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EFFETS DE CERTAINES VARIABLES SUR LES PRODUITS DE FILIATION DU THORON DANS DES MILIEUX RADIOACTIFS ARTIFICIELS

par

J. Bigu*

RÉSUMÉ

Les effets des concentrations d'aérosols et d'humidité relative, des ventilateurs mélangeurs, des générateurs d'ions négatifs, et d'un petit appareil servant à la précipitation de poussière électrostatique sur la concentration de l'activité des produits de filiation du thoron aéroportés ont été étudiés. L'étalonnage a été effectué dans une grande installation expérimentale, modèle plein-pied, utilisée pour les essais sur le radon et le thoron. Les niveaux de concentration des produits de filiation du thoron ont monté considérablement avec l'augmentation de la concentration d'aérosols. La mise en marche des ventilateurs mélangeurs et des générateurs d'ions a eu un effet considérable et opposé sur les niveaux de produits de filiation du thoron par rapport aux résultats obtenus avec les concentration d'aérosols.

Mots-clés: Produit de filiation du thoron; Rayonnement; Milieu.

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INTRODUCTION

The effect of mixing fans on radon progeny, under laboratory-controlled and field conditions, has been investigated by several authors (Ab82; Bi83; Ho79a; Ho79b; Sh72; and Wr69). The effect of mixing fans and ion-generators on thoron progeny has been studied by the author and the results have been reported elsewhere (Bi84a).

Experiments on thoron progeny were carried out in a small (3 m^3) radon/thoron chamber under conditions of low aerosol concentration (~1.0 x 10^3 cm^{-3}) and low relative humidity (30-40%) in order to investigate plate-out phenomena. Furthermore, the effect of an ion-generator on aerosol concentration using NaCl was also studied (Bi84a). In all cases, the effect of the ion-generator was to lower thoron progeny and aerosol concentration. The operation of a mixing fan had the effect of lowering the thoron progeny concentration.

In this paper, the above experiments have been extended to other environmental conditions such as higher aerosol concentration and relative humidity. Furthermore, the experiments have been conducted in a large Radon/Thoron Test Facility (RTTF) of the walk-in type (Bi84b). More specifically, the effect of aerosol concentration, relative humidity, mixing fans, negative ion-generators and a small electrostatic dust precipitator, on thoron progeny concentration has been investigated.

EXPERIMENTAL APPARATUS AND MEASUREMENTS

Aerosol consisting of an aqueous solution of NaCl (1 g/L) was injected into the RTTF by means of an aerosol atomizer model 3075/3076 in conjunction with its corresponding air supply system, desiccator column and Kr-85 electrical charge neutralizer unit, all manufactured by TSI (U.S.A.).

Thoron/thoron progeny atmospheres were produced using commercially available ^{228}Th dry-sources of the flow-through type model Th-1025 manufactured by Pylon Electronic Development (Ottawa, Canada).

Commercially available, modestly priced ion-generators, some purchased in a large department store, were used. Up to four ion-generators were employed, i.e., Bionaire 100 (filament only, no fan), Bionaire 2000 (filament and two-speed fan), Bionaire 500S (filament and fan; filament will not operate without the fan), and Pollenex 99 (same as Bionaire 500S). Bionaire ion-generators are distributed in Canada by BioTech. The Pollenex generator is manufactured by Pollenex (U.S.A.). The experiments with mixing fans were conducted using the fan of some of the ion-generators with the filament off. The effect of the ion-generator alone was investigated with ion-generators which had either no fan (Bionaire 100) or ion-generators in which the filament and fan could be operated independently.

A small electrostatic dust precipitator (MSA Electrostatic sampler) model F, manufactured by Mine Safety Appliances Co. (U.S.A.) was used in the experiments.

Aerosol concentration was measured with two condensation nuclei counters (CNC), namely a TSI model 3020 and Rich model 200, manufactured by Environment One (U.S.A.).

Environmental variables such as air temperature, relative humidity and barometric pressure were measured by means of probe models 602, 604 and SD 001, respectively, in conjunction with a data logger model 650, manufactured by alpha-NUCLEAR (Toronto, Canada).

Thoron progeny levels, i.e., Working Level, WL(Tn), ^{212}Pb concentration, [^{212}Pb], and ^{212}Bi concentration, [^{212}Bi], where the square brackets are used to denote activity concentration (mBq/m^3), were measured using a two gross α-count method.

RESULTS AND DISCUSSION

The results of the experimental tests are given in Tables 1 to 6 and Figure 1.

Figure 1 shows WL(Tn) and the aerosol concentration, N, versus time. There is a dramatic increase in WL(Tn) with increasing N. However, the rate of increase for WL(Tn) was substantially lower than that corresponding to N. Constant aerosol concentration conditions were attained in about 3 hours after continuous aerosol injection. Figure 1 shows that 65% of the final value of N was reached in less than 1 hour, whereas it took more than 2 hours for WL(Tn) to attain 65% of its final value. These times depended, of course, on air flow conditions in the RTTF. A time lag between N and WL(Tn) suggests itself from the above data.

Table 1 shows radon progeny data, some of which have been used in Figure 1. Experiments were conducted at 26-27°C, with a relative humidity of 52%. The aerosol concentration before aerosol injection was $\lesssim 1.0 \times 10^{-3}$ cm^{-3}. Under steady-state conditions N reached a value of ~2.8×10^{4} cm^{-3} after about 3 hours of continuous injection. As the RTTF was operated at a low air exchange rate, i.e., long air residence time, N only decreased slowly after aerosol injection was terminated. Table 1 shows the following interesting features:

1. WL(Tn), [^{212}Pb] and [^{212}Bi] increased markedly after aerosol injection. The thoron progeny increased in a similar fashion and rate as that of WL(Tn), see Figure 1;
2. The ratio [^{212}Bi]/[^{212}Pb] decreased significantly shortly after aerosol injection and then increased again reaching values slightly larger than before aerosol injection. This appears to be a transient effect; and
3. As expected, the ratio [^{212}Pb]/WL(Tn) remains essentially constant, with a

maximum variation of less than 2.5%, as ^{212}Pb contributes about 90% to WL(Tn).

Table 2 shows the effect of relative humidity on WL(Tn) and the thoron progeny. Also shown in the Table are the aerosol concentration and the temperature, T, in the RTTF. There is a significant increase in WL(Tn), i.e., ~36%, with increasing relative humidity from 34% to 70%. This effect cannot be attributed to the aerosol concentration because N did not follow the same pattern as WL(Tn). The thoron progeny ratio remained essentially constant with a variation within ±5% of its mean value.

Table 3 shows the effect of two ion-generators on WL(Tn), and the thoron progeny concentration. Also shown is the aerosol concentration. Tests were conducted at 25°C and at a relative humidity of 31-34%. One of the ion-generators, i.e., the larger one, had a fan whereas the smaller ion-generator had a filament only and no fan. The data shown were obtained when the filaments were on but the fan was not operating.

Data on October 4 were obtained with the small ion-generator. Data on October 7 were obtained with the two ion-generators operating simultaneously. The following effects induced by the ion-generator are worth mentioning:

a) WL(Tn) and the thoron progeny concentration were reduced when the ion-generators were operated;

b) Operation of the ion-generators caused a decrease in the aerosol concentration;

c) The effect of the two ion-generators operating simultaneously was larger than the effect of only one; and

d) The converse of items a) and b) is also true, i.e., the effects are reversible.

For the cases presented here, a decrease in WL(Tn) of 29% was caused by turning the small ion-generator on for a few hours (October 4/85). An

increase in WL(Tn) of 77% was caused when the ion-generators were turned off on October 7/85. The much smaller starting values for WL(Tn), [^{212}Pb] and [^{212}Bi] on October 7/85 are due to the fact that the ion-generators were turned on on October 6/85 and left on until 9:00 next day.

Table 4 shows the effect of two ion-generators when only the fans were turned on and the filaments were turned off. One of the two generators was the same as the one used the previous day (Bionaire 2000); the other generator was a different one (Bionaire 500S). The effect brought about by the ion-generator fans was greater than the effect with the filaments on and fans off. As previously reported (Bi84a) the effect of the fans was to decrease WL(Tn) and the thoron progeny concentration. A 5-fold reduction was observed in these tests. Furthermore, the fans had an effect on the thoron progeny concentration ratio; it decreased when the fans were operating. The experiments were carried out at 24.5^{o}C and at a relative humidity of 35%. The aerosol concentration was in the range 1.3 x 10^3 - 1.75 x 10^3 cm^{-3}.

Table 5 shows the combined effect of four ion-generators operating simultaneously, with fans and filaments on, on WL(Tn) and the thoron progeny concentration. Also shown is the aerosol concentration. Experiments were conducted at 27.0-29.0^{o}C and at a relative humidity of about 48%. Quite a dramatic effect was observed in this case, i.e., a 30-fold reduction in WL(Tn) and [^{212}Pb] after about 3 hours of ion-generation operation. The thoron progeny concentration ratio was also dramatically affected. As indicated above, the aerosol concentration decreased as the ion-generators were in operation, and vice versa.

Table 6 shows the effect of a small, and rather old, electrostatic dust precipitator on WL(Tn), and the thoron progeny concentration. The effect observed in this case was rather low because of the relatively large dimensions of the RTTF and the limited capacity of the precipitator. In

contrast to other designs, however, this precipitator had no protective barrier material at the air intake, e.g., thin layer of 'foamlike' material which acts as an effective 'filter' of entering radon and thoron progeny.

CONCLUSIONS

As expected, thoron progeny levels increased markedly with increasing aerosol concentration. The operation of mixing fans and ion-generators had a substantial and opposite effect to aerosol concentration on thoron progeny levels. Furthermore, the operation of ion-generators significantly decreased the aerosol concentration in the RTTF. It is suspected that the ions produced by the generators may act as nucleation sites with the formation of larger particles. A lowering of the aerosol concentration may, in turn, reduce airborne thoron progeny concentration, and increase plate-out of these products on large surfaces, e.g., walls. In general, the data presented here are qualitatively consistent with data for radon progeny reported previously by the author elsewhere (Bi83).

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Table 1 - Thoron progeny and aerosol concentration data in the RTTF. Operating conditions were: 26-27°C (temperature) and 52% (relative humidity.

Time	WL(Tn)	[^{212}Pb] (Bq/m^3)	[^{212}Bi] (Bq/m^3)	[^{212}Bi] / [^{212}Pb]	[^{212}Pb] / WL(Tn) (Bqm^{-3} WL^{-1})	[^{212}Bi] / WL(Tn) (Bqm^{-3} WL^{-1})	N (cm^{-3})
8:00	1.13	323.1	148.4	0.46	285.9	131.3	875
8:40	1.03	296.7	130.8	0.44	288.1	127.0	942
9:00	1.44	420.5	131.8	0.31	292.0	91.5	7.3×10^3
10:00	5.52	1610.5	473.4	0.29	291.7	85.8	1.95×10^4
11:00	8.33	2402.6	968.9	0.40	288.4	116.3	2.35×10^4
12:00	10.48	3010.4	1340.2	0.44	287.2	127.9	2.60×10^4
13:00	11.18	3193.2	1590.5	0.50	285.6	142.3	2.69×10^4
14:00	11.51	3284.8	1685.9	0.51	285.4	146.5	2.75×10^4
15:00	12.38	3530.7	1815.3	0.51	285.2	146.6	2.78×10^4

Note: Aerosol was injected at 8:41.
N stands for aerosol concentration.

Table 2 - Thoron progeny concentration and relative humidity data in the RTTF. (Aerosol concentration also shown)

Time	WL(Tn)	[^{212}Pb] (Bq/m^3)	[^{212}Bi] (Bq/m^3)	[^{212}Bi]/[^{212}Pb]	[^{212}Pb]/WL(Tn) (Bqm^{-3} WL^{-1})	[^{212}Bi]/WL(Tn) (Bqm^{-3} WL^{-1})	Nx10^{-3} (cm^{-3})	Relative Humidity %
8:30	-	-	-	-	-	-	-	34
8:50	4.14	1184.0	589.8	0.50	286.0	142.5	2.65	34
9:50	4.17	1195.1	583.1	0.49	286.6	139.8	3.0	38
10:50	4.43	1269.1	614.6	0.48	286.5	138.7	2.4	59
11:50	-	-	-	-	-	-	2.3	64
12:50	5.33	1517.0	788.1	0.52	284.6	147.9	2.0	66
13:50	5.21	1483.7	785.5	0.53	284.8	150.8	2.1	68
14:50	5.58	-	-	-	-	-	2.0	69
15:50	5.50	-	-	-	-	-	2.1	70

Note: Experiments were conducted at 24-25°C.

Table 3 - Effect of ion-generators on thoron progeny (Filaments only).

Time	WL(Tn)	[^{212}Pb] (Bq/m^3)	[^{212}Bi] (Bq/m^3)	[^{212}Bi]/[^{212}Pb]	Nx10^{-3} (cm^{-3})
8:10	0.73	206.8	119.9	0.58	1.0
8:50	0.80	229.0	115.8	0.51	0.70
9:00		ION-GENERATORS TURNED OFF			0.75
9:50	0.96	275.6	132.5	0.48	1.40
10:50	1.13	324.9	141.3	0.43	1.50
12:50	1.29	370.0	170.6	0.46	1.30
13:50	1.20	344.5	169.8	0.49	1.55
14:17		ION-GENERATORS TURNED ON			-
14:50	1.18	339.3	155.4	0.45	1.70
15:50	1.07	-	-	-	1.70

Notes: i) RTTF operating conditions: 25°C and 31% relative humidity.

ii) Bionaire models 2000 and 100 were used.

Table 4 - Effect of ion-generator on thoron progeny (Fans only)

Time	WL(Tn)	[^{212}Pb] (Bq/m^3)	[^{212}Bi] (Bq/m^3)	[^{212}Bi]/[^{212}Pb]	Nx10^{-3} (cm^{-3})
8:05	1.04	300.8	127.6	0.42	-
8:15		FANS TURNED ON			1.45
8:50	0.34	98.4	26.3	0.27	1.30
9:50	0.22	65.9	7.4	0.11	1.55
10:50	0.21	61.8	6.3	0.10	1.55
11:00		FANS TURNED OFF			-
11:50	0.52	152.1	27.7	0.18	1.65
12:50	0.64	185.7	74.4	0.40	1.75
13:50	1.14	329.7	112.5	0.34	1.70

Notes: i) RTTF operating conditions 24.5°C and 35% relative humidity.

ii) Bionaire models 2000 and 500S were used.

Table 5 - Effect of ion-generators on thoron progeny (Filaments and fans).

Time	WL(Tn)	[^{212}Pb] (Bq/m^3)	[^{212}Bi] (Bq/m^3)	[^{212}Bi]/[^{212}Pb]	Nx10^{-3} (cm^{-3})
8:05	9.96	2823.1	1635.4	0.58	-
8:15		ION-GENERATORS TURNED ON			-
8:30	-	-	-	-	1.30
8:50	0.95	251.6	111.0	0.44	0.60
9:50	0.32	96.2	14.8	0.15	0.55
10:50	0.29	88.8	11.1	0.12	0.42
11:50	0.31	92.5	7.4	0.08	0.55
12:00		ION-GENERATORS TURNED OFF			-
12:50	1.86	547.6	129.5	0.24	1.25
13:50	3.74	1087.8	370.0	0.34	1.75
14:50	5.06	1457.8	603.1	0.41	2.09

Notes: i) RTTF operating conditions: 27-29°C, 47% relative humidity.

ii) Four ion-generators were used.

Table 6 - Effect of electrostatic precipitator (EP) on thoron progeny.

Time	WL(Tn)	$[^{212}Pb]$ (Bq/m^3)	$[^{212}Bi]$ (Bq/m^3)	$\frac{[^{212}Bi]}{[^{212}Pb]}$	Remarks
8:10	2.94	839.9	432.2	0.51	EP off
8:40	2.97	843.6	460.3	0.54	EP off
9:20	2.96	843.6	428.8	0.51	EP fan on, filament off
9:50	1.83	521.7	262.0	0.50	EP fan and filament on
12:30	2.25	642.7	328.2	0.51	EP fan on, filament off
12:40	2.85	784.4	425.1	0.54	EP off
13:00	3.06	873.2	434.7	0.50	EP off

Note: Precipitator filament voltage 12500 V DC.

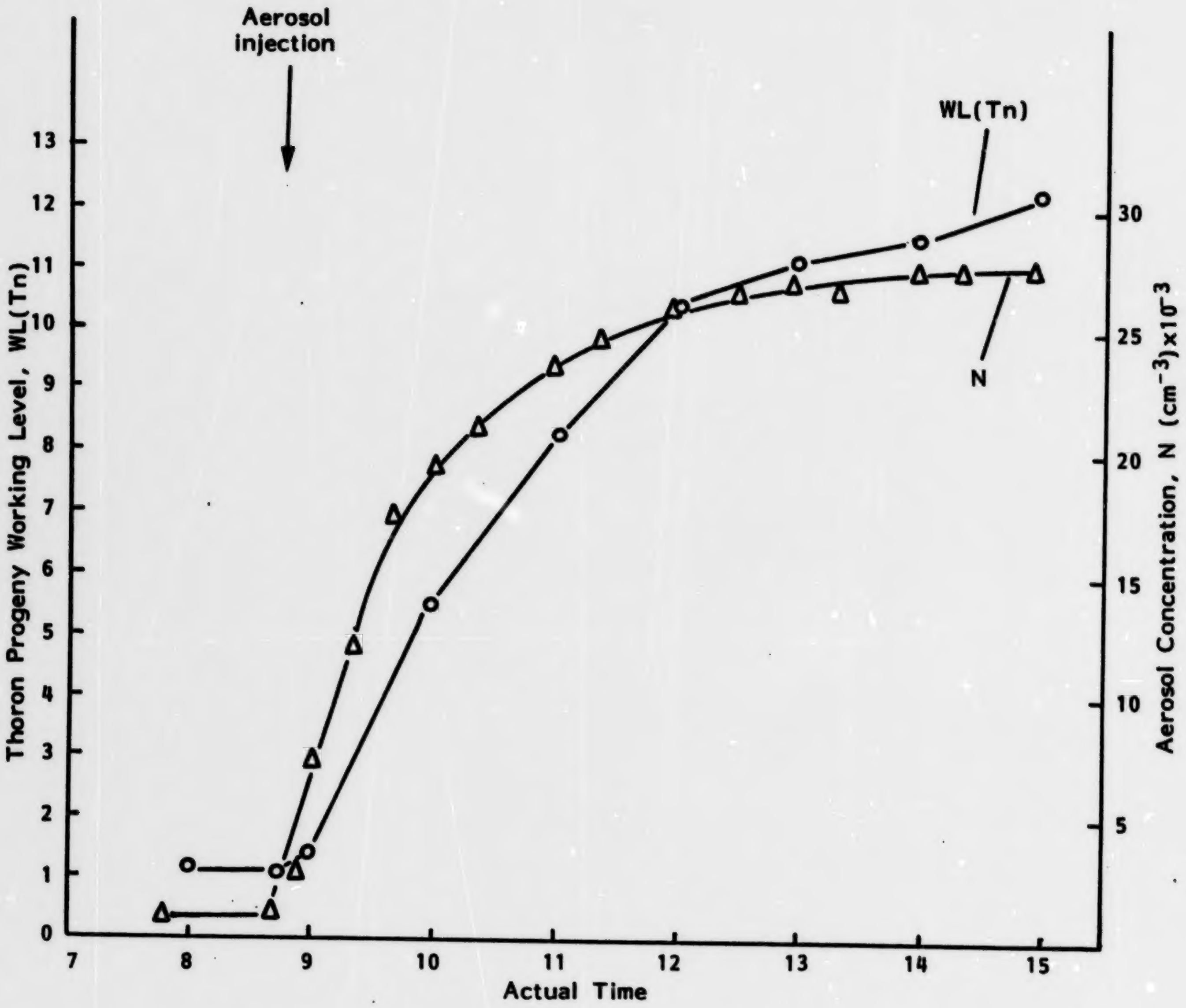

Fig. 1 - Thoron progeny Working Level and aerosol concentration versus time.